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Model-Based Systems Analysis--
A Methodology and Case Study

by

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In the past fifteen years, the computer industry has seen extraordinary changes for the better in hardware development, operating systems, and programming languages. In the hardware area, new circuitry and other techniques have, for example, enabled computer performance at equivalent cost to approximately double every year since 1950. (1) Operating systems, virtually non-existent in 1953, are now a way of life. In addition to increasing computer throughput, these increasingly comprehensive operating systems today allow the implementation of many applications which were barely imagined a dozen years ago. Finally, the move from machine languages and basic assembly languages to higher level languages such as Fortran IV, Cobol, PL1, (and an increasing number of user-oriented special purpose languages) has reduced considerably the time necessary to translate from human-sensible program specifications to machine-sensible code.

Unfortunately, improvements in the "front end" of the process of converting systems from manual to machine processing have been almost negligible over this same time span. This "front end", the processes of systems analysis and design, has been rather sadly left without major changes in approach or methodology throughout the years. I state nothing new. Moravec voiced this same complaint in 1965:

> Analyzing a corporate date system is still a primitive process. Although the computer has revolutionized data systems in the past decade, there has been no corresponding revolution in the procedures of installing and operating them. The rationale for determining what data to analyze and how to go about it and the basic techniques for interviewing, documenting, flow charting, and analyzing have changed little since the advent of the computer. Indeed, they have not changed greatly since the nineteenth century (2).

More recently, Canning has pointed to the "painfully slow response" to management needs provided by the current techniques of systems analysis and design (3). Nor are these two alone in their comments. Words like "cumbersome tools" and "the tendency to simply copy the old system over into the new" sprinkle the great bulk of the literature on the subject.

Today, most of the more common traditional programmed* functions of business management, such as payroll and order entry, have been already translated into computer processing. To handle new and less well understood functions, which are now of greater interest, the old techniques of systems analysis and design are sadly lacking. In order to effectively perform systems analysis and design in these newer areas, a new framework is necessary. In the area of systems design, model-based systems design as espoused by Carroll (5) and others appears to be one key to innovation and greater certainty of results in the fabrication of a new system.

The step which precedes the design step in the data processing conversion process is, however, also in need of a new framework. It is this initial systems analysis step (sometimes referred to as the "systems study") with which this paper is concerned. After a discussion of existing conventional systems analysis theory and tools, a three-pronged, model-based, systems analysis theory will be presented.

First, let us pause to establish some definitions. In general, the process of converting from a manual system to an automated on has been divided into three steps, systems analysis, system design, and programming.

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*In the sense of programmed versus non-programmed functions as described by Simon (4).

"Analysis . . . is finding out <u>what</u> is to be done; design is finding out <u>how</u> it should be done; programming is <u>making</u> the specified system a reality." (6) The distinction, as performed in practice, is not as clear cut. "As we know, the people called systems analysts actually do some of the work called systems design and, in some cases, so do the programmers." (8) There is extensive interaction between phases of the process. However, the analysis function, no matter when performed, is clear. It "is restricted to fact-finding and to examining systems to learn how they work . . . " (8)

<u>Conventional Systems Analysis</u>

Conventional systems analysis is described in varying ways by different authors. (9, 10, 11, 12, 13) The process, however, is in general agreed upon by most as a series of steps dominated by interviews of operating personnel and data collection in the area to be studied. Typical of these formulations is a five-step program for the system analyst presented by Gregory and Van Horne. They suggest that the systems analyst should:

> "First, <u>obtain facts</u> by interviewing people and observing activities about the events--their type, volume, and timing--that lead to the origination of documents, maintenance of files, issuance of reports, processing steps done at each work station, and flow of documents between stations.
>
> "Second, <u>collect sample copies</u> of filled-in documents, ..."
>
> "Third, <u>study processing operations</u> to learn the how and why of every document that each person receives or issues..."
>
> "Fourth, <u>organize the facts</u> obtained into flow charts, flow lists or other suitable form to trace the path of data from origin, through each stage of communication and processing, into files, and out of files to reports.
>
> "Fifth, <u>interview each user</u> of documents and reports to learn what information he uses in his work and what he thinks he needs." (14)

To assist him in studying a system, the system analyst has conventionally had a limited kit of tools and techniques. In the last few years, this kit has been expanded slightly, primarily by adding the tool of simulation, but the methodology of systems analysis has remained much the same. The system analyst's current tool bag contains the following:

Data Gathering Techniques

1. Interviews. In any discussion of systems analysis techniques, the interview ranks high, and usually highest. It is referred to by many authors as perhaps the most "fruitful" form of securing information. (15) Instructions on interviewing are available from several sources, usually heavily laden with the language of social and personal psychology. Drawbacks in this technique are fully recognized. Analysts have been warned that "personal interviews can become confused, redundant, and time-consuming ... The position and personality of the person being interviewed can inject a pronounced bias to an interview.." (16) Despite these drawbacks, for lack of a better mechanism, interviews have remained the number one tool in systems analysis.

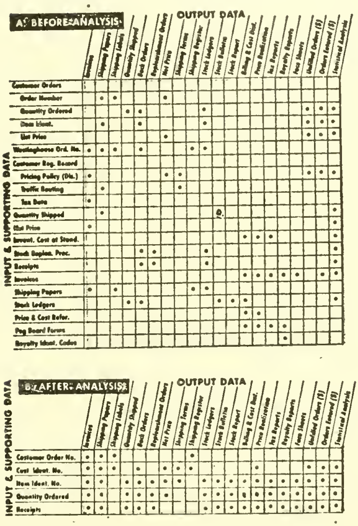
2. Data Collection Forms. During the past decade and a half, a plethora of special data collection forms to assist in systems analysis have been devised and exhibited. In general, these forms present a uniform method of listing the contents of documents worked upon at a particular clerical station and of noting the volume of each document.

3. Input/Output Charts. One helpful technique which results in a compact portrayal of the data items utilized in a system is the input-output (I/O) chart. As shown by Exhibit 1, data items are listed on one axis of the chart, and the output documents utilized are listed on the other axis.

Exhibit 1

Input-Output Chart*

INPUT AND OUTPUT OF CUSTOMER ORDER PROCESSING FOR STOCK ITEMS



*Reproduced from Evans, M. K. and Hague, L. R., "Master Plan for Information Systems," Harvard Business Review, Jan-Feb 1962, p. 98.

The use of I/O charts leads to an identification of the significant data items in the particular system being analyzed. It allows the elimination of redundant data item inputs. Finally, it focuses attention on often-used permanent types of information which should be stored on a master file. (17)

4. Statistical Sampling Techniques. It has long been recognized that a relatively few well-chosen observations will permit inferences to be drawn regarding the total population from which the sample was drawn. In order to reduce system study costs, these techniques have necessarily been utilized.

5. Estimating. As a last resort, where the above techniques have been unsuccessful in gathering data, the analyst often has turned to his data gathering tool of last resort--estimating. Not much is written about this tool, but it is often used.

Data Presentation Techniques

6. Systems Flow Charts. Two techniques are used by systems analysts to describe the logical flow of the procedures that have been studied. The first, and most widespread, is the technique of flow charting. Exhibit 2 shows a typical flow chart of a procedure. Included are the most ubiquitous symbols, the rectangle for procedure steps, and the diamond for decision points. Approximately a dozen other symbols are in common use, the majority representing different types of storage media.

7. Decision Tables. The other major technique utilized by systems analysts to exhibit procedural flows is the decision table. Shown in Exhibit 3, a sample decision table illustrates, in a more compact form, the logic from the flow chart which was presented in Exhibit 2.

The popularity of decision tables is due to three factors. They are

Exhibit 2

Sample Flow Chart

Accounts Receivable - Statement printing and collection/dunning procedure

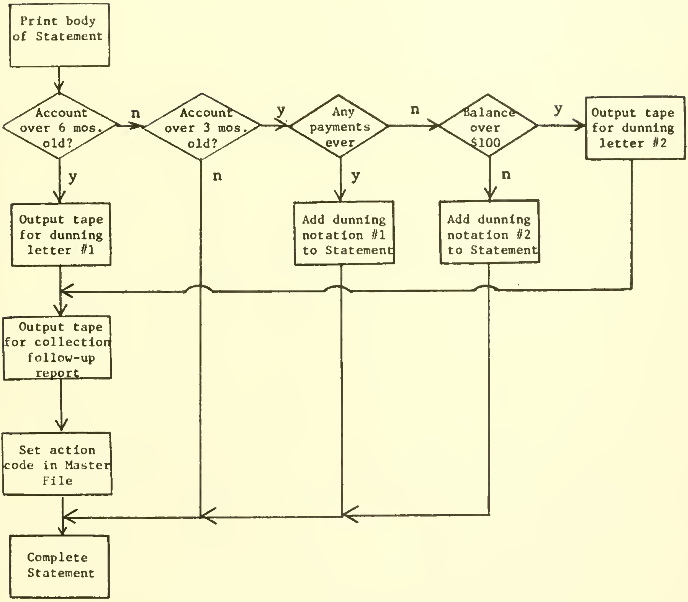


Exhibit 3

Sample Decision Table

Condition Entry

		Alternative One	Alternative Two	Alternative Three	Alternative Four	Alternative Five
IF (condition)	Account over 6 mos. old	Y	N	N	N	N
	Account over 3 mos. old	-	N	Y	Y	Y
	Any payments	-	-	Y	N	N
	Balance over $100	-	-	-	N	Y
THEN (action)	Print body of statement	X	X	X	X	X
	Output tape for dunning letter #1	X	-	-	-	-
	Output tape for dunning letter #2	-	-	-	-	X
	Output tape for collection report	X	-	-	-	X
	Set action code in master file	X	-	-	-	X
	Add dunning notation #1 to statement	-	-	X	-	-
	Add dunning notation #2 to statement	-	-	-	X	-
	Complete statement	X	X	X	X	X

Action Entry

Coding

Y = Yes
N = No
X = Action to be taken

compact. They are an important aid for the programmer since the program logic is neatly laid out. Finally, they can be automatically translated into some machine languages, eliminating further programming steps.

8. Simulation. The most recent weapon which has been added to the system analyst's limited arsenal is that of simulation. Although primarily reported as a tool for systems design (18,19), simulation is also valuable in the analysis process. Systems which are not completely understood can be simulated using the data obtained in the system study. In this way, it can be ascertained that each of the individual parts of the system has been correctly understood. If the parts as analyzed, can be synthesized into an accurate working simulation of the system, the inference can be drawn that the analyst has succeeded in the comprehension of the system.

Model-Based Systems Analysis

The above tools and techniques have, for nearly two decades, answered the question of "How does one go about the process of systems analysis in the data processing field?" Their weakness, however, is that the significant questions in the systems study field are not begun with the interrogative "how" but rather with "what." The truly serious questions for the systems analyst are "What should I look at?" and "What is the best approach to understanding this system?"

These questions, I would submit, are best answered by turning to model-based systems analysis. The analyst who has a model of the area he is researching firmly entrenched in his consciousness will, it is argued, do a faster and more effective job of systems analysis.

The importance of this approach was suggested by Pounds' "The Process

of Problem Finding." (20) Concerned with the question of how managers determine which problems they must act upon, Pounds postulates that managers have models which they compare with the existing real world situation at a particular time. When significant differences are noted between the actual situation and the model, the manager notes the existence of a problem. Pounds suggests that four major types of models are used by managers. These are historical models, planning models, other people's models, and extraorganizational models. A very simple example of the planning class is the budget. If a manager finds that he has spent $100,000 for direct labor in a period during which only $80,000 was budgeted, he notes the existence of a problem.

The system study is, to a great degree, a problem-finding process. I believe the goals of the process (the design of a more effective and efficient information system) are best served if the primary view of the systems analysis process is taken from the elevation provided by a Poundsian problem-finding approach. Where the systems study is merely seen as "finding out how the current information can best be computerized" important dimensions of the process can be overlooked. As will be stressed in the following case study, model-based, problem-finding, systems analysis assists in ensuring (1) that no important areas of the system are overlooked, (2) that deficiencies in the current process are identified and improved, and (3) that the information system is designed to be able to adjust to and take advantage of improvements in the basic process as they are carried out.

The Traditional Use of Same-Application Models

Although not formally labeled as such, one type of model-based procedure has been the framework for much traditional systems analysis. The use of a

same-application model has often been introduced into the analysis-design-programming continuum in one or more of the following ways:

-- The computer equipment salesman has provided documentation of the same application as performed in another similar company.

-- A computer software package for the application, while not used, has been investigated to ascertain the logic utilized, to "look for good ideas," and to ensure that no vital area or benefit of computerizing the system has been overlooked.

-- The systems men have taken trips to other installations to see a similar application and to question the methodology used in designing the system.

-- Finally, the manufacturer's systems engineers or consultants with experience in the same application area have been called upon to assist in the analysis and design process.

Each of these possible steps makes use of models of the same application area. The systems analysis, as well as design, process followed by the company often has been significantly altered through contact with these models.

The Use of "Internalized" Models in the Marketing Area

The marketing area differs significantly from most traditional data processing application areas. The necessary data to aid marketing management, and the systems to process this data in more than a rudimentary form, were

until recently uncertain and undesigned, respectively. With the exception of some retrospective sales analysis reports, little had been done in the computer field to aid the marketing manager until early in the 1960's. The pioneers in the field had to develop new approaches. One of these was model-based. Using the internalized market models of top managers as a starting point, and simulation as a tool, Amstutz and his co-workers were able to perform effective systems analysis in a highly unstructured area. (22)

Model-Based Systems Analysis in Newer Application Areas

Yet a third model-based approach can be utilized for other application areas which are not well defined--especially those outside the traditional scope of industrial applications. I would suggest that appropriate models to be used by the systems analyst in particular in the increasingly important sectors of medicine, education, and local government can be found in models of similar processes which have been thoroughly researched and developed in the industrial sphere.

In areas where little attention has been given to the management process in the past, a suitable perspective on the process is often lacking. Appropriate models, which are after all only structures from which to view a particular situation, can provide this perspective. Their greatest strength lies in assisting the systems man to stand back from the process he is analyzing--and to gain perspective so that he can take into account all the important aspects of the process.* The tendency merely to automate currently

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*Langefors implicitly recognizes this need for additional frames of reference when he cites as his first proposition in his theory of systems analysis the fact that "People tend to neglect the importance or the existence of things they are not able to see or perceive." (23)

Zannetos has also suggested that normative models be given greater importance in management systems determination. (24)

perceived information needs can thus be countered.

The primary use of these reference models in systems analysis, to assist in the problem-finding process, will be developed at length in the remainder of this paper. There are, however, several subsidiary reasons for the systems analyst to locate and study all possible perspective-giving normative models before commencing to analyze an area. Utilization of models provides additional benefits to the systems analysis team since knowledge of the models assists in developing:

1. Some insight on the part of the study team into the most efficient overall plan for the study.

2. Better initial communication with personnel within the department(s) studied.

3. An ability to ensure that parts of the system which are highlighted in the models are not overlooked by the systems team. In effect a "check list" of activities which should be studied is developed.

4. Possible structures around which to design the new system when the study emphasis is shifted from systems analysis to systems design.

An Example of Model-Based Systems Analysis--The Appointment Reservation Process at the Lahey Clinic

The model-based, problem-finding, system analysis technique was used at the Lahey Clinic in Boston to study the patient appointment scheduling system in use at that clinic. The Lahey, located in a major urban area is a dis-

tinguished medical group practice of approximately 100 doctors. Its primary service is an "out-patient" or ambulatory practice which is, in effect, a collection of doctors' offices together with the necessary facilities to perform medical tests such as x-rays and chemical analysis of body fluids.

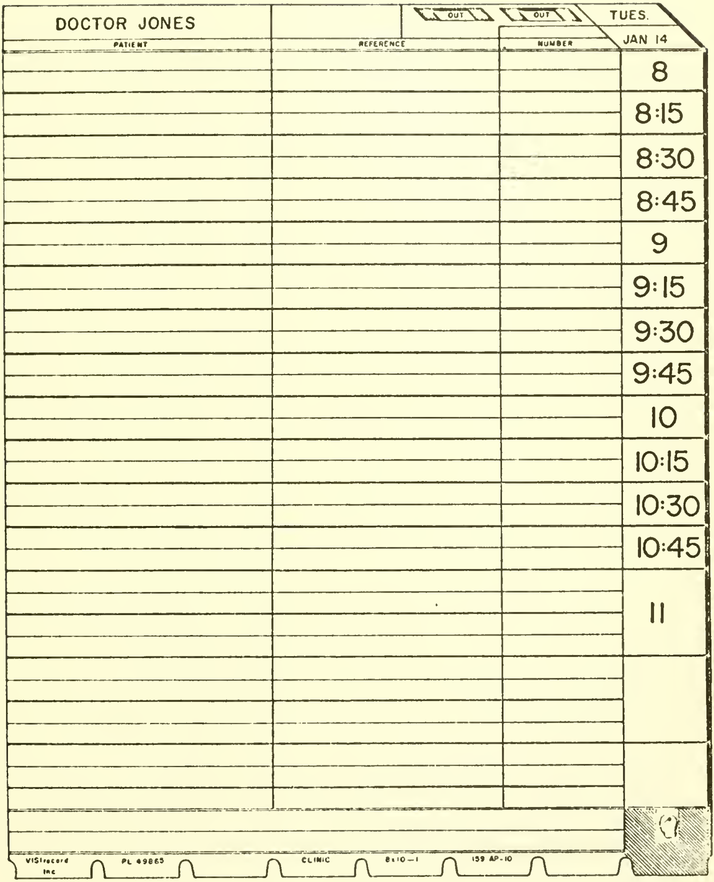
The area to be investigated at the Clinic was that of reserving time for patients. This function, which fits into Anthony's category of an operational control system (25) is primarily performed by a department called the Central Appointment Office.

In the Central Appointment Office a group of 25 secretaries schedules appointments for the clinic's physicians and for a few major medical tests. Each doctor's available time, divided into 15-minute periods, is shown on a card (Exhibit 4) for each day--with the cards for the next three months available to the appointment personnel at any one time.

Depending on the circumstances of a patient's appointment request, an appointment secretary decides to which physicians and for which tests the patient should be scheduled. An attempt is made to schedule patients as fully as possible to all physicians whom the secretaries believe the patient should see. The choice of departments and doctors for which a patient is scheduled is dictated by a set of rules developed by clinic medical management.

The scheduling of <u>tests</u> by the Central Appointment Office (CAO) is quite limited. In general, the CAO schedules only a half dozen, major, time-consuming tests, such as electrocardiograms, electroencephalograms, and intravenous pyelograms.

The scheduling of <u>doctors</u> is, however, extensive. The CAO's task is more difficult than merely to schedule patients to the correct one or more



<u>Exhibit 4</u>

<u>Lahey Clinic Scheduling Card</u>

of the 12 major departments (e.g., general surgery, neurosurgery, urology, internal medicine, etc.). An attempt is also made to schedule the patient to the appropriate sub-specialty within a department (for instance within internal medicine, to sub-specialties such as cardiac, vascular, etc.). Furthermore, an effort is made to steer specific patients to particular physician sub-sub-specialists who are interested and expert in one disease or particular area (i.e., diabetes, liver malfunction, etc.).

In all cases, the appointment secretary must select from an inventory of available doctor and test time a feasible and hopefully optimal[1] series of appointments for a patient. The clinic's management originally viewed the process as akin to the airlines reservation process, and the initial charge to the systems effort was in these terms.

The Problem in Brief

Early in the feasibility study the problem was seen to be quite complex. Each patient who enters the clinical facilities of a group practice represents a unique problem and has a need to see a particular set of specialists and to utilize a specific set of test facilities. The problems of determining exactly which physicians and major tests should be scheduled, and in which order these should be scheduled, appears to be a relatively impossible task for a group of lay secretaries many without any medical experience whatsoever. Yet the secretaries were seen to make both the facility (doctor and/or tests) and ordering choices to build a schedule for each patient.

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[1]The schedule should be "optimal" in terms of choosing the correct doctors and tests while also minimizing the patient's time spent at the Medic Center in the diagnostic process.

In making these choices, the appointment secretaries were seen to face a major dilemma which can be summarized as follows:

> On the one hand, if the secretary schedules the patient to see more doctors than he requires, there is a high probability that the first doctor to see the patient will cancel the excess appointments; and that the suddenly released (and therefore available doctor time) will not be used by other patients. There is no backlog of patients waiting to be moved up automatically in the queue for a doctor if another patient's appointment is cancelled.
>
> On the other horn of the dilemma, if the patient is scheduled to see fewer doctors than necessary, it is quite possible that the additional doctors for whom the patient should have been scheduled will be booked completely on the day the patient enters the clinic. This may place a heavy burden on the patient. If the patient is from out of town, he may have to extend his stay in a hotel. If he is a local patient, he may have to make another trip to the clinic.

Determination of Models to Use

The initial model, a simple reservations system, appeared too limited to deal with what was, in effect, a major scheduling problem. Two other models appeared to be more applicable on an *a priori* basis. The first was a model of the traditional type--a composite model drawn from the study of systems utilized by *other* group practices. The second was an industrial job shop scheduling model.

The "Other Clinic" Simple Scheduling Model

At least on the surface, the process of scheduling patients through a multiple-specialist medical practice appears to be fraught with uncertainty. "In the general case involving a new patient, a nervous and perhaps somewhat embarrassed prospective patient attempts to explain often vague symptoms over the telephone to a secretary who has had minimal, if any, medical training. The secretary must then translate this dubious evidence into a series of appointments for the patient with the correct specialists for the correct amount of time for each visit." (26)

These evident inherent difficulties in scheduling doctors have led most multi-specialist clinics to make the decision that the above uncertainties are not to be dealt with at the clerical level. A straightforward scheduling model utilized at most other clinics ensues from this decision.

This model is implemented through three major scheduling canons. They are:

1. If a patient desires a complete medical examination, no attempt whatsoever is made by the schedulers to determine the patient's condition for scheduling purposes. The patient is merely given the first opening available for a physical examination with any member of the staff who performs complete physical examinations.

2. No attempt is made by the clerical scheduling personnel to develop a full routing for the patient. Only the first appointment is scheduled in the manner noted above.

3. Appointment time length is standardized. In most cases, complete physical examinations are assumed to take one hour. All other appointments are assumed to take 15 minutes.

Given the above rules, the patient arrives at the clinic scheduled to see an initial physician. The remainder of the routing is performed by the first doctor whom the patient sees. The routing is done only after the patient has been given a complete physical examination by the doctor. As a result, the doctor is the scheduler. And the scheduling is done on the day that the patient arrives at the clinic. Since there is no need for one group of secretaries to have access to all the appointment cards (so that they can <u>pre</u>schedule patients to all necessary physicians), most appointment cards are kept in each physician's location--on a <u>decentralized</u> basis.

<u>The Job Shop Model</u>

The process of looking at other clinics appointment systems (i.e. the use of same-industry models for comparative purposes) has, as previously mentioned, been hallowed by data-processing tradition. The utility of the industrial model chosen, the job shop model, was not as clearly evident. However, upon comparison, the job shop scheduling model appeared to be a good match to the clinical reservation (by now regarded as a scheduling) system. The systems are alike in basic structure. Each is characterized by a set of <u>facilities</u> which perform work; a <u>routing</u> procedure to direct a set of <u>items</u> through the facilities; <u>precedence relationships</u> which provide a necessary ordering of facility visits; unique <u>service times</u> for the items undergoing processing at a particular facility; <u>waiting time</u> during which the item is inactive; and a <u>basic scheduling point</u> from

which the item's "loading" to the various facilities is offset. Furthermore, both the job shop and clinical scheduling systems have two scheduling modes with regard to time: static scheduling, a loading of facilities to some preset limit before the actual day of operation, and dynamic scheduling, which reschedules facilities continuously taking into account the latest events and conditions until the moment each segment of the schedule is executed. Finally, each system has a criterion function, by which its output may be judged.

In order to validate that the job shop model was at least roughly equivalent to the patient scheduling system, some additional comparisons were made for each of these dimensions. The equivalence in each area is as shown in the following paragraphs.

In the job shop, the facilities are a set of machines of which various subsets or machine groups exist. All the machines in a machine group have the same general performance characteristics. However, the groups are usually further subdivided. For instance, within a machine group of boring tools, there may be a subgroup of automatic borers, the setup time for which makes this subgroup efficient for long runs but not for short jobs. Many machines, within groups, are interchangeable. For any operation, one type of machine, not specifically designed for that operation, may be substituted for the specialized machine, with some loss in efficiency.

The facilities in the clinic are basically of two types. They consist of physicians and test facilities. The doctors in a group practice are most often highly specialized. Like the machines of the job shop, usually they are also available in multiple copies with similar specialties; that is, there are "physician groups" just as there are machine groups. In medical practice, physicians are divided among approximately a dozen major specialties, such as

general surgery, orthopedic surgery, internal medicine, urology, allergy, etc.

As in the job shop, within these general groups, there are also subgroups. A notable example is internal medicine, which has well-recognized subspecialities such as cardiac, vascular, hematologic, and thyroid. In addition, however, today there are often sub-subspecialities. An example of this is a hematologist who has particularly concerned himself with leukemia. Although physicians are somewhat interchangeable, there is, as in the job shop, some loss in efficiency in using a doctor whose prime field is allergy, for example, to see a patient with a thyroid condition--_if the thyroid condition is definite or highly probable_.

The _items_ in the job shop are _products_ that must be developed during their travels through the various machines. These products are usually fed through a series of machines by a _routing procedure_.

The _items_ in the _clinic_ are, quite simply, _patients_. Just as there is a _routing schedule_, which moves a product through a machine shop, so there is an _appointment schedule_, which moves a patient through the clinic. Just as there is an optimum routing for a product through various specialized facilities, so there is an optimum appointment schedule for each patient. For each patient, there is a given set of doctors whom the patient should see and a preferred series of tests that should be performed on the patient.

The routing procedure in the job shop usually includes rather tightly defined _precedence relationships_ (a product must first be bored, before it can be reamed, before...,etc.). There are also many definite _precedence_ relations in the _clinic_ scheduling problem. For example, an appointment with the orthopedic department must be arranged _before_ a barium swallow test is given if both are to take place on the same day. (The reason is that the orthopedic specialist

may order roentgenograms that might be obscured by previously ingested barium.)

In the job shop, production time is the time spent at each facility while the product is worked upon. Waiting time is the "dead" time enforced upon the product or subproduct by delays due to the unavailability of a machine, the lack of availability of material, poor scheduling, etc. In general, waiting time involves a cost to the shop--without visible progress in the movement of the product toward its completion. The costs involved are primarily the cost of storage space and the interest cost involved in holding the semifinished inventory.

In the clinic, production time is the time spent with each doctor or during the actual performance of each test. Waiting time in the clinic is time in which the patient is not involved in any of the activities listed under production time. In general, the cost of this time to the clinic is minimal as long as the waiting is kept below a certain threshold. Above that threshold, the cost to the clinic may rise dramatically as patients become bored, nervous, unhappy and, ultimately, walk out of the clinic.

In the job shop, the due date is usually the basic scheduling point, for the original schedule at least. The facilities are usually scheduled in reverse order to that on the routing sheet, taking into account the production time necessary at each facility and the availability of each facility. (27)

In the clinic, the basic scheduling point is usually the entry time into the clinic. As with due dates in the job shop, this basic scheduling point can be negotiated. Usually, the routing determined for the patient is scheduled forward from this entry time.

To date, most formal job shop scheduling has been static scheduling, primarily the loading of machines by means of Gantt charts. Only recently, with

digital computers becoming scheduling tools, has centralized dynamic scheduling come into being. In the job shop, factors such as machine breakdowns, poor materials, cracked forgings, and items that test as unacceptable, render the current shop schedule no longer optimal--and possibly not feasible. For these reasons, which reflect the uncertainties in production, schedules must be reassessed dynamically.

Like the job shop, patient scheduling has static and dynamic versions. At the present time, almost all patient scheduling is of the static variety. However, the need for dynamic rescheduling is also present. Static schedules quickly decay while being executed in the medical setting also under the effects of service-time variations, patient no-shows, physicians' lateness, and other factors.

The criterion function in the job shop varies from shop to shop. In general it includes weights for such factors as job tardiness, inventory costs, costs of hiring and firing, costs of working overtime, and other factors.

There is also a criterion function for the patient scheduling problem. As in the job shop, it is a combination of several variables with the weighting of each differing with diverse managers. The prime variables for the clinic criterion function are doctor idle time, patient waiting time, and the cost of the scheduling system.

Problem Finding

An analysis of possible problem areas as detected by comparing the two models with the actual system at the Medic Center revealed some significant potential problem areas. Pounds states that "...the word 'problem' is associated with the difference between some existing situation and some desired

situation." (28) This definition can be broadened to suggest that even if it is not certain that another specific situation is "desired," the search for problems can fruitfully take place when differences are noted between an existing situation and a possibly desired situation. The difference between the systems portrayed by the two models which have just been discussed and the Medic Center system were numerous.

Differences Between the Other Clinic System and the Medic Center System

Three major differences were noted between the "other clinic" model and the Medic Center system. First, the "other clinic" model did not incorporate multiple-appointment clerical routing of patients; while the Medic system included extensive clerical routing through a series of carefully chosen specialists. Second, the "other clinic" clerical scheduling system was decentralized, while the Medic system was based on a centralized CAO. Finally, the scheduling rules in the other system, because of the nature of the system, were simple and straightforward; in the Medic system, they were extremely complex.

Differences Initially Noted Between the Job Shop Model and the Medic Center System

The differences between the Medic scheduling system and the job shop model were more extensive. They arose primarily because both the facilities and the item being processed in the medical situation were human beings, not machinery and raw materials. One difference existed in the routing area. In the job shop, the routing of a product through machines is fairly easily determined. In the medical case, the routing was seen to be very uncertain and heavily dependent upon good communication of symptoms from the patient to the scheduler and efficient interpretation of these symptoms by the clerical scheduler.

Another apparent major difference existed in the area of scheduling pro-

duction time. In general, a machine or class of machines can be expected to perform its assigned tasks at a certain rate. The complex relationship between physician and patient, however, appeared to make scheduling the correct amount of "production" time for each patient appointment hugely more uncertain in the clinic scheduling case than in the job shop.

A third major difference between the job shop model and the Medic system appeared in the handling of clerical work. An increasing number of industrial organizations are now performing job shop scheduling by computer. As Emery has pointed out, even Gantt chart-like computer-assisted <u>static</u> scheduling in the manufacturing area helps to avoid infeasible loads, decreases clerical errors, and increases the ability on the part of the schedulers to manipulate extensive data files. (29) In addition, a <u>dynamic</u> computer scheduling system in an On-Line Real-Time (OLRT) configuration has the ability to monitor the current situation on the shop floor as well as to react to unpredictable stochastic occurrences, such as a machine breakdown, in the job shop. Rescheduling can be performed taking the <u>current</u> situation into account. The Medic scheduling system, however, was a manual system incapable of reacting to the dynamic system state.

Conventional Systems Analysis

These differences between the models and the Medic system pointed directly at several possible problem areas. In summary, potential problems were indicated by the models in the areas of patient routing, time allotted for each appointment, centralization versus decentralization of scheduling, the complexity of scheduling rules, dynamic stochastic process "faults," clerical errors, and clerical inability to perform effectively because of limited data availability or data

handling capacity. Conventional systems analysis was, therefore, performed with particular attention given to these potential problem areas.

A Final Delineation of Problems

At the conclusion of the systems analysis the conventional volume figures had been gathered and data flows recorded. More importantly, some 17 major reasons had been assembled as to why the actual scheduling system at the Medic Center was less than optimal. Of these 17, by far the majority had been previously targeted as possible problem areas by the models/current system comparison and had, therefore, been precisely investigated during the systems study process. A review of the problems which were uncovered illustrates the assistance provided by the models in the problem-finding process.

Nine of the 17 problem areas which were found concerned the static scheduling system. Eight affected the dynamic schedule.

Problems Concerning Static Scheduling: The nine problem areas in static scheduling were as follows:

1. Routing. By far the most obvious problem area was that of incorrect routing of a patient. Although routing efficiency varied for different types of patients, some categories had error rates as high as 40 per cent (i.e. only three out of five appointments ultimately kept by a patient during the initial series of appointments were originally scheduled correctly for him by the CAO). An analysis on these routing errors lea to an interesting conclusion. By far the major reason for the errors was the failure of the appointment secretary to elicit enough information from the patient. In each case, the missing information was obtained by the

physician during the patient's initial appointment. Importantly, in most cases, the obtaining of these facts appeared to require only the simpler "extractive" talents of the physician (the ability to get more verbal information from the patient) rather than diagnostic ability. Examples of these cases are shown in Exhibit 5.

2. "Production" Time. A second major problem area was identified as the wide dispersion of patient time with the doctor ("production time") around the mean time scheduled for each appointment. Exhibit 6 shows a histogram of time actually taken by 235 patients each scheduled for 15 minute appointments in three clinic departments. The mean of the service times is 14 minutes--but the standard deviation approaches eight minutes. The process of estimation of probable production time at each station is well developed for the job shop. Production time for any operation is determined from a set of fully-researched standard times.

   When a scheduler attempts to estimate the "production time" involved in a patient's visit to a doctor's office, however, he has no such standards available. There is much more uncertainty about the amount of time necessary. This uncertainty stems primarily from the fact that doctors are much more variable in their working output than machines and that the patients in the clinic do not present their medical problems for solution in as predictable a manner as materials present their properties for machining.

3. Centralization of Clerical Processing. A third problem area which

Exhibit 5

SCHEDULING ERRORS CAUSED BY INSUFFICIENT INFORMATION

1. A 20-year-old patient who was quite deaf asked for a "general checkup." An added appointment with ENT was necessary.

2. A patient had been taking medication for a thyroid condition for years but did not mention it. A consultation was added with a thyroid specialist.

3. A male patient had a very bothersome urinary problem. It was not mentioned to a female appointment secretary. Consultation with urologist added.

4. A heart condition was not stated to the appointment secretary, although the patient's doctor was treating it. Cardiac consultation added.

5. Patient stated hemorrhoids and sinus trouble to doctor, but not to secretary. Two appointments added.

6. Only a general checkup was asked for by the patient. A specific history of long-standing abdominal pain was, however, related to the physician.. One additional consultation.

7. Endocrinology consultation added when the primary doctor found the patient had been taking medication for adrenal insufficiency.

8. A woman did not mention gynecologic problems until she saw the initial doctor. A male secretary had made the appointment.

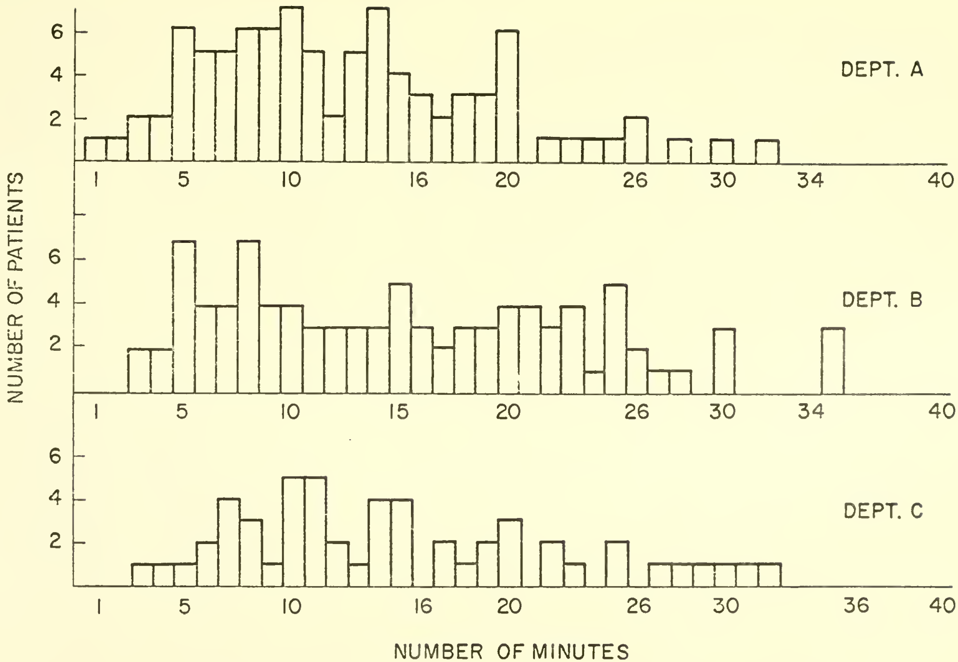

EXHIBIT 6. SERVICE TIME IN THREE DEPARTMENTS, OLD PATIENTS

was noted can be summarized in the statement that "a centralized scheduling system lacks the advantages of a decentralized system and vice-versa." Using pencil and paper technology, the scheduling cards can be located only in one place. Thus, in the Medic's centralized system, when a doctor receives a direct call from a patient who requests an appointment, he does not have his appointment book available so that he can determine the best time for the patient to come in. He must either go through the sometimes lengthy telephoning process of finding an available time from the CAO or guess at the best time for the patient to come in.[2] The ability to handle efficiently this particular situation is the prime advantage of a decentralized system which has the appointment schedule located at the doctor's station. The centralized system as practiced at the Medic Center, on the other hand was found to have eight major advantages. Most of these concerned ease of multiple appointment scheduling and consistency of scheduling.

4. Difficulties of Schedule Rearrangement. A fourth major reason that the scheduling at the Medic Center was seen to deviate from a desirable pattern was its manual mode of operation which made the rearrangement of future schedules difficult. A scheduler was not able to search and rearrange schedules to provide an improved appointment series for each

[2]Rather than go through the lengthy process of (a) contacting the appointment office, (b) waiting for the secretary to locate his schedules for the next several days, (c) having the schedules read to him, (d) juggling the mental pictures of schedules to choose the best time, and (e) telling the patient when to come in, the physician often provides the patient with a day and time when he hopes he has a light schedule.

patient after other appointments were made or cancelled. An attempt was made to optimize the schedule of each patient _only_ when he was _originally_ scheduled. Because of the volume of appointment requests, the limited information retrieval possibilities in the current system, and the constantly changing patient load, no attempt could be made to improve schedules dynamically as later changes asserted their impact on the system.

5. _Inaccessible Data Base_. Schedules were also badly developed because of the inaccessibility of information about the patient to the appointment office. The clinic has much data in its possession which can not be extracted economically by the appointment scheduling personnel when needed.

   A significant amount of information that could assist in scheduling the patient is recorded in the patient's medical record. In order to make use of this information, the records were obtained by the appointment office upon receipt of letters from former patients. Before each of these patients was scheduled, his history was checked for the following items:

   a. Doctors whom the patient had seen in the past
   b. The date the patient was last seen at the clinic
   c. Instructions of clinic doctors concerning appointments or tests they wished the patient to have when he next entered the clinic

   It is apparent that any of these scheduling-assisting items might also be found in the histories of former patients who _telephoned_ to request

appointments. Histories were not requisitioned, however, on telephone calls. It was assumed that the appointment secretary would elicit these items of information from the patient on the telephone. The secretary, however, was not always able to obtain the necessary data from the patient.

The histories were not requisitioned on telephone calls for several reasons--the most important being that telephone calls from patients outnumbered mail requests for appointments by more than 3-1 and the economics of obtaining the additional records was regarded as prohibitive.

6. Clerical Error. Simple clerical errors were a sixth source of scheduling problems. Secretaries could easily pick the wrong card on which to post information. Occasionally, appointments given to patients were not entered on the card. Thus, the appointment time was also given to a second patient. Nurses sometimes gave patients appointments and, in the hurry of the day, did not notify the Central Appointment Office. In addition, rewriting and multiple manual transformations of data provided many chances for error.

7. Incomplete Set of Scheduling Rules. A further source of some problems was that the scheduling rules were not completely responsive to all situations. In job shop terms, routing instructions were unclear.

8. Routing of Local Patients. Another problem area in static scheduling is actually not a problem area for the clinic. However, it was seen to be a problem for the patient. One scheduling rule stated that local

patients were to be scheduled conservatively. It was assumed that the local patient could return to the clinic for secondary appointments and tests. This is desirable from the clinic's viewpoint, since the physicians are scheduled only for those appointments that will, with a high probability, be kept. For the patient, however, it sometimes means additional visits to the clinic. These visits would not be necessary if the appointment secretary were able to determine the exact schedule the patient should follow before the first patient visit to the clinic.

9. Lack of Feedback to Secretaries on Scheduling Performance. A ninth problem area was found in that there was no feedback in the static system to allow secretaries to evaluate their success or failure in scheduling patients. The manual nature of the scheduling system made such a feedback system on a continuing basis prohibitively expensive.

Problems Concerning Dynamic Scheduling. Eight problems were "found" which inhibited the dynamic performance of the scheduling system. These were:

1. Patient "No-Show." Patients sometimes did not "show-up" for their appointments, without calling to cancel. On the average three per cent of all appointments were no-shows.

2. Doctor Lateness. Doctors were late either for personal reasons (not very prevalent) or for medical reasons (held at the hospital by an operation or emergency situation). Physicians were late for their first appointment, on the average, by approximately 10 minutes.

3. Patient Lateness. This was not a major factor. A study of 456 patients showed that less than 10 percent were late, and the majority

of these arrived less than 15 minutes late--well within the average waiting time. The patient was most likely to show up several minutes early for this appointment.

4. Randomness of Patient Time with the Doctor. Patients in general re-required more or less time than scheduled because of the randomness over and above the need for better time scheduling noted in static problem. No matter how accurate a time-per-appointment scheduling system is developed, it will still be impossible to estimate service times with complete accuracy.

5. Late Cancellations. There was a significant number of unreported late cancellations of appointments by patients (or by doctors for the patients). These are appointment cancellations received by the doctors twelve or more hours before appointment time that never were reported to the Central Appointment Office; thus, the availability of an appointment time was not made known. About 2 appointments in 100 were affected in this manner.

6. Other System Failure. Slowness or failure in other clerical systems within the clinic often meant that information needed for an appointment was not available. The patient therefore could not be seen at the scheduled time. Two systems within the clinic were often slow in responding to requests so that needed information was not available to the doctor at the time the patient was scheduled. These systems were:

   a. The Medical Record Provision System. Approximately 2 percent of appointments were affected by nonarrival of a medical

report. When this occurred, the waiting was often lengthy.

b. The System for Reporting of Test Results. The doctor's diagnostic process depends heavily on the results of tests that he orders. To complete the diagnosis, or to discuss the problems with the patient, for every visit after the first, the physician must have the test results available to him.

7. Uncertainty of Test-Reporting Time. As patients see physicians, the doctors order tests to be performed. In many cases, it was seen to be desirable for the test results to be ready, both:

   a. before the patient returned to see the doctor who ordered the test and also

   b. before the patient saw another consultant (such as a surgeon) whose decisions might be made partially on the basis of the test result.

   Laboratory and other tests, in general, are performed within a fairly well-defined amount of time. In addition, there is a well-defined time gap in reporting the result. However, the amount of time necessary to perform and report the results of each particular test were not clearly understood by the schedulers. As a result, appointments were often scheduled either too close to each other (with test results therefore unavailable) or too far apart (with patients spending more time in the clinic than necessary).

8. Dynamic Visibility of Schedule Status. Visibility can be defined as the

ability for personnel in the central scheduling area to comprehend the dynamic situation regarding patient waiting queues in the entire clinic at any point of time.[3]

The "dynamic situation" in which each doctor finds himself at any point during the day was seen during the study to be completely invisible to the Central Appointment Office and to every other doctor. The length of the queue waiting to see the doctor, the time the doctor was due to leave, the probable amount of time it would take to complete the schedule for that morning or afternoon, etc.; all of these things were unknown for any doctor, except to that doctor and his nurse. (In addition, the last factor, probable time until completion with the current load, was unknown even to that particular physician unless he stopped to make an estimate.)

The telephone was used to overcome this lack of visibility. Where information was needed about the dynamic situation regarding a particular specialty or group of specialties, by the CAO, or other areas, a telephone call to a nursing station made a small segment of the clinic visible to the inquirer. However, the sampling speed was slow. The information gained was often fragmentary and sometimes

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[3]In effect what is being suggested in this section is the global perspective available when all data are in one place and are capable of being manipulated. The SAGE system (30) and SABRE (31) were early applications of this principle. More recently Carroll has worked on the job shop setting attempting to assess the advantages of the "visibility" provided by global information for scheduling decisions. (Global information is knowledge of the status of the entire shop as opposed to the more "local" information known only at a machine group.) Carroll has recently found global data to be of significant value. (32)

incorrect. It had the possibility of being biased by the desire of a nurse to keep a doctor from being overworked or herself from working overtime.

As a result, the clinic could be likened to a set of compartments each completely walled off from the others. Only through human-and-telephone contact (with all the inherent faults listed above) could a person in one compartment see through to understand the current clinic dynamic situation.

The Models and Problem-Finding

It is interesting to note that, of the 17 problem areas discussed above, twelve of them were directly indicated by the differences noted earlier between the models and the Medic system. This group includes the first seven problems in the static scheduling area and problems D1-D4 (all stochastic disrupting events) and 8 in the dynamic scheduling group. In addition one other problem (D5--late cancellation not being reported) was strongly hinted at by the models and pursued from this starting point.

Four problems were not apparent from the models-Medic comparison. These four (S-8 "routing of local patients," S-9 "lack of feedback to the secretaries," D-6 "other systems failure" and D-7 "uncertainty of test reporting time") were uncovered for the first time during the conventional systems study.

Three Major Solution Areas

Rather than dealing with 17 isolated problems, it is more fruitful to look at them in terms of solutions. Looked at in this way the problem space

just developed became more manageable. The 17 problems factored into three major solution areas. These areas are as follows:

1. The Need to Obtain More and Better External Information About Patients. "External information" is defined as information not currently in the files of the clinic. This is basically information about new patients and their symptoms. It also applies however to former patients whose physical condition may have changed significantly during their absence from the clinic. The information is necessary primarily for the routing of patients. The solution for part of static subproblem number 7 falls into this category together with static subproblems 1 and 8.

2. The Need to Devise Better Estimates of the Time that Each Specific Patient will Spend with the Doctor on Each Appointment. Given the very large variations in time actually spent with the doctor as opposed to time scheduled, it was seen that the lack of a better time estimate per visit allowed significant fluctuation in doctors' schedules. Since this problem affected every patient visit scheduled, it was in itself a prominent problem. It is static subproblem 2 stated above.

3. The Need for More Effective Access to the Information Currently Available in the Clinic and for a Greater Ability to Manipulate this Information. Under this last heading were combined all the remaining problems. In the static area, the issue of centralization-decentralization (static scheduling problem number three or in static notation "S-3") was primarily one of access to the same information from various points in the clinic. Without an on-line computer system, one can have the advantages of either centralization or decentralization. However,

both sets of advantages are desirable. Inaccessibility of the data base (S-5) is a classic problem often solved by improved information processing techniques. The three remaining static problems, clerical error (S-6), the ability to rearrange schedules efficiently (S-4), and feedback (S-9) are all problems in effective data manipulation.

In the dynamic area, it was assumed that no major steps could be taken to eliminate the existence of dynamic subproblems 1 to 4, but their _effects_ could be ameliorated by a dynamic information processing system in the same manner as Emery and others have suggested for the job shop.

The remaining four problems (dynamic 5 to 8) also fall into this final category for their solutions. "Other systems failure" was placed in this category because the failures cited could be removed by more efficient information-processing techniques in the areas concerned. The solutions to "late cancellations" and the "lack of visibility" problems also fell into the scope of improved information handling techniques.

The problem of "failure to fully integrate the time it takes to perform and report tests..." (D-7) can only be solved by better data handling. Human scheduling cannot cope with the myriad of test scheduling and performance times in more than a general manner.

...and the Solutions

Possible solutions to each of these problem areas were also seen to be available. They are as follows:

<u>A solution to the need for external information to aid in routing</u>. Work on the solution of the problem of the need for additional information about the patient for routing purposes was begun immediately following the end of the systems analysis phase. Encouraging progress toward the solution of the problem has been described elsewhere (33) Efforts are currently based on an extensive computer-processable symptom questionnaire mailed to new patients requesting appointments. Symptoms indicated by the patient are analyzed by a computer program to determine the best schedule for the patient.

<u>A solution to the problem of production time</u>? Research has not yet been completed in this area. The work done thus far has indicated that better approximations than the current two-distribution approach can be made to the length of time that a patient spends with a doctor. One specialty group has been studied to determine the prognostic effect of various patient variables, notably current diagnosis, and age on the length of appointment time. The results suggest that the variance between scheduled time and actual time spent with the doctor can be reduced by a factor of two. Further research is being performed.

<u>A solution to the data-processing problems</u>. Working from the results of the conventional systems analysis (performed as directed and abetted by the problem-finding process), an on-line real-time computer configuration has been designed as the primary instrument to increase data-handling capability to meet the clinic's scheduling needs. The system centers around the relatively modest capabilities of an IBM System 360/30 with less than a dozen CRT terminals. Four files have been

designed. These are:

1. A <u>doctor schedule</u> file containing basic information about each physician's schedules.

2. An <u>available appointment</u> file which is checked for time availability for each physician when appointments are scheduled or cancelled.

3. A <u>patient active appointment</u> file which contains data about each patient currently scheduled with an appointment, including the time of each appointment scheduled.

4. A <u>patient master</u> file containing extensive data for all patients considered to have a high probability of returning to the clinic whether or not appointments are currently scheduled for them.

The conventional systems analysis which was performed established the transaction volumes, necessary file sizes, input requirements, output requirements, and desirable processing techniques. The model-oriented, problem-finding systems analysis approach, however, established the need for the system as well as clearly delineating the most important system characteristics. These characteristics are as follows:

(1) The time segments for appointments are being established in the computer system in such a manner that they can be adjusted to allow for multiple time periods, not just the dual-length system

of 15 minute and one hour segments. (The initial design, in fact, allows for multiples of time minutes and currently has four appointment-length choices. As mentioned above, further operations research is being performed to establish additional desirable time segments.)

(2) The ability to computer-route patients from a symptom questionnaire is being built into the system to increase the accuracy of routing.

(3) Although the initial system is to be operated from the Central Appointment Office only, (for economy, training, system backup, and simplicity of operation reasons) the system design includes an ability to ultimately perform input-output operations on a decentralized basis also so that the advantages of both centralized and decentralized scheduling can accrue.

(4) The direct access patient master file is being included in order to allow the appointment secretary to have access to salient scheduling data.

(5) The system, although designed initially as a static scheduling system, will be left open-ended in order to allow for eventual utilization of its potential in the dynamic scheduling area.

(6) Emphasis during the design process has been put on coordination with "other systems" such as laboratory data processing and medical record retrieval to take into account the effect these subsystems have on the entire patient scheduling system.

Would these same specifications have been developed without the model-based systems analysts approach? Possibly. If the conventional systems analysis process had been approached with imagination, and the signals from the environment correctly evaluated, the same specifications might have resulted. However, even if this is granted (and it is by no means certain--since more than two-thirds of the problems were suggested by the models) the model-based approach allowed a much faster zeroing in on the major problem areas. And it provided, in effect, a check-list for the analyst of what areas should be investigated. The uncovering of problem areas, it is suggested, was made more automatic--less dependent on the talents of a particular analyst.

SUMMARY

A model-based, problem-finding systems analysis technique has been presented. It is suggested that this technique assists in structuring the environment in which the analyst will work. The technique further allows the analyst to uncover the major problems existing in the current system and assists in avoiding the all too common problem of merely "automating the current misinformation system."

Three different types of model-based systems analysis have been identified. The first is the conventional usage of "same-applications" models. The second is the method suggested by Amstutz for marketing systems analysis. The final type, the use of other-industry models for industries such as medicine which historically have not had much attention from management scientists, is suggested here.

The problem-finding aspect of model-based studies it is suggested, tends

to identify problems not before recognized--or given full credence--and to reveal those areas which need additional operations research. Through the use of this technique, insights are gained into further existing operational control problems and therefore into the information system necessary to support operational decision-making. The technique helps to ensure that (1) no important areas of the system are overlooked, (2) that deficiencies in the current process are identified, and (3) that the information system is designed to be able to take advantage of improvements in the basic process as they are developed. In addition, there are subsidiary benefits from the process in terms of providing the analysts <u>prior</u> to the study with a better understanding of the area, better communication potential with people employed in the area, and a better base from which to plan the study itself.

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